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Aeromedical Support for Casualties in Extremely Hot Climates

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Aeromedical Support for Casualties in Extremely Hot Climates

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1. SUMMARY

Aeromedical support for operations in hot climates involves exposure to acute heat injury and chronic heat stress which are unfamiliar to many medical personnel in NATO nations. Preparation for deployment to a hot climate should include review of climatic data for the site, appropriate adjustment to supplies and equipment needed to handle predicted numbers of heat casualties, and education of all air base personnel regarding methods of preventing heat illness. Medical facilities at the remote site may include local buildings or air transportable units. Special care is required with respect to housekeeping and provision of safe food and water in hot climates. Casualties arriving from remote sites should be assumed to suffer from heat stress and dehydration; those with elevated temperatures or disturbed consciousness must be treated as heat stroke cases until proven otherwise. Oral rehydration mixtures should be used whenever possible, reserving intravenous fluids for severe cases. Plans for air evacuation of all patients should attempt to minimize heat stress during loading and allow for continued rehydration in flight.

2. INTRODUCTION

Heat illness develops in the presence of heat-induced dehydration, cardiovascular decompensation, and/or an injurious rise in body temperature. Symptoms range from subtly impaired performance to frank illness, incapacitation and death. Military operations in desert or tropical climates can involve a high incidence of primary heat injury cases as well as significant numbers of heat-related disorders in casualties of other types. In addition, continuous heat stress increases fluid requirements and produces chronic fatigue and loss of appetite affecting patients, medical staff and air base personnel.

The combination of heat stress and trauma with limited treatment resources is not commonly encountered at medical training centers in temperate climates. Aeromedical personnel supporting operations in hot climates may find themselves with responsibilities ranging from implementation of protective measures for air crew members and maintenance personnel to treatment of frank heat casualties among combat forces. The importance of effective prevention cannot be overemphasized, as heat stroke is equivalent to major wounding and is associated with a high fatality rate (1). Heat stroke survivors are lost to further service for periods of weeks to months and may never again be fit for duty under hot conditions (2).

The authors are developing written materials to assist aeromedical personnel in handling the unaccustomed climatic extremes and suboptimal hospital conditions which they may encounter upon deployment to hot climates.

3. HEAT STRESS AND ITS EFFECTS

Heat stress occurs when some combination of climate, activity and clothing causes body heat load to reach or exceed heat dissipation to the environment. Military operations often amplify climatic heat stress by demanding sustained physical work under very hot conditions. Problems may also develop in relatively cool weather when personnel must wear protective clothing which interferes with convective cooling and the evaporation of sweat. Chemical defense patient-wraps pose a potentially serious heat stress problem in hot climates. Another highly provocative condition is work in sun-heated, enclosed spaces such as parked aircraft, workshops or tents.

Response to a given thermal stress varies widely among individuals and from one day to the next. Heat tolerance is greatest among personnel who are physically fit and are already acclimatized to heat. Although there is no gender difference *per se,* small body size and low aerobic capacity are risk factors for either sex. Other risk factors include lack of acclimatization, intercurrent illness, dehydration, nutritional deficit and cumulative fatigue. Heat stress effects are significantly lowered when there is periodic relief such as retreat to air-conditioned quarters or a strong nocturnal temperature drop.

Adequate water intake becomes critical in hot conditions because evaporation of sweat is the main path for dissipating body heat and the

only cooling mechanism when air temperature exceeds body temperature. Daily fluid requirements increase dramatically with work and climatic heat load; Fig. 1 shows that even persons resting in the shade may require several liters of fluid per day.

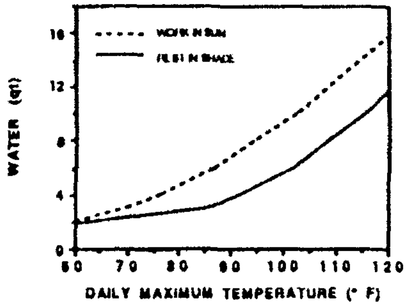

Fig. 1. Daily water requirement from Adolph EF, et al. Physiology of Man in the Desert. New York: Interscience. 1947, p. 121. 1 qt = 0.946 L.

Aircrew members require special consideration because even moderate heat stress can impair their performance enough to tip the balance toward mission failure or even loss of an aircraft. Preventive measures for flying personnel are detailed elsewhere and include protection from preflight heat stress and scheduling which allows for heat-induced fatigue. Inflight heat stress is worst for missions which involve low-level flight and/or evasive maneuvers. Aircrew members should be warned that heat and dehydration reduce acceleration tolerance by 0.5-1 G and increase susceptibility to decompression sickness.

4. PREPARING FOR DEPLOYMENT

Aeromedical personnel preparing for deployment in support of hot-weather operations should review authoritative summaries of preventive measures (3,4) and treatment of heat casualties (5,6).
Liaison should be established with flying personnel and support services to educate all with respect to the special challenges of operating in extremely hot weather. The incidence of heat casualties will depend not only on weather but also on the concept of operations and the possibility of protective modifications such as scheduling work at night. Use of NBC clothing can produce heat casualties even in temperate climates. It is therefore extremely important that aeromedical personnel work with commanders to help them understand the potentially critical impact of heat stress, the beneficial role of acclimatization, and the fact that humans cannot function without adequate water intake.

Every effort should be made to obtain detailed climatic data for the deployment site. Desert regions are often characterized by stable weather patterns with very hot daytime temperatures and cold nights due to radiation cooling. Paradoxically, desert shores can be very humid. Tropical conditions usually involve continuous heat stress with high humidity. Potential sources of site-specific information include base weather offices and central meteorology data banks. The following data should be obtained for each month throughout the year.

- Mean daily high and low air temperatures
- Distribution of daily high and low temperatures (percentile values or ranges)
- Mean wet bulb temperatures or dewpoints corresponding to known air temperature readings
- Mean daily high and low values for Wet Bulb Globe Temperature (WBGT) or other indices
- Wind and cloud cover information
- Times of sunrise and sunset

It is not adequate to have mean daily temperature alone or humidity data without associated temperature readings. If the only available information comes from atlases or country summaries, data must be interpreted with respect to local conditions such as the altitude of the air base or proximity to large bodies of water. Regular communication with the nearest meteorological office should be set up to keep personnel apprised of current and predicted weather conditions.
Before departure, medical personnel should familiarize themselves with organizational responsibility for water supply, food and shelter together with possible sources of ancillary equipment such as generators, fans, air conditioners, refrigerators and freezers. Additional preparations for handling large numbers of heat casualties include:

- Adjust stockage of supplies to allow for heavy use of oral and intravenous fluids
- Obtain thermometers to measure rectal temperature to 45 °C (113 °F)

- Plan for special heat stroke cooling stations with water, ice, fans and life support equipment

Extraordinary measures may be required where the normal supply system cannot provide rapid modification to the Table of Allowances (TA). The first USAF aircrew members deployed to the Persian Gulf carried intravenous solutions and administration sets in their personal kit. If oral rehydration mixtures are not included in medical supplies, the following mixture can be used: To one liter (quart) of water add 40 grams of table sugar and 6 grams of table salt.

5. MEDICAL FACILITIES

Patient care areas and staff quarters in hot climates should be situated to minimize heat stress. Indigenous buildings should be used where possible because they usually are designed and sited to take advantage of prevailing breezes and often have thick walls which moderate daily temperature peaks. In the absence of refrigerated air conditioning, effective low-tech alternatives include evaporative cooling, natural or forced ventilation with outside air, and ceiling fans.

In addition to discomfort for patients and staff, high temperatures in medical facilities cause difficulties with housekeeping and equipment maintenance. It may be necessary to set up cooled storage areas for critical equipment and supplies to assure a reasonable shelf life. It is especially useful to have portable air conditioners and fans adaptable to AC and DC power sources. On arrival, medical personnel should establish communication with the meteorological office together with a system for advising base personnel regarding current and predicted temperatures and related weather conditions.

5.1 Air Transportable Clinic (ATC)

The USAF's ATC is designed to provide support to an operational squadron of 300-500 personnel in a bare-base setting. It is primarily intended for outpatient treatment and assumes that more serious cases can be transferred to a nearby hospital or immediately evacuated by air. The ATC should be sited to take advantage of any shade, prevailing breeze or other benefits offered by the surroundings.

Review of the TA shows that the clinic is not well suited to treatment of multiple heat casualties. Relevant equipment items in the TA include six oral thermometers, 12 L each of lactated Ringer's solution and normal saline, one urinary catheter set, a 150-L storage reservoir for heat-sterilized water, and 18 m of water hose with a nozzle. There is one ice bag, but no mechanism for chilling water or producing ice. Supplies for oral rehydration were recently added. The ATC's capacity for treating multiple heat casualties may be increased by adding supplies for oral rehydration as well as increased quantities of parenteral solutions, I V administration sets, and urinary catheter sets. In the absence of laboratory facilities, patients will have to be assessed for heat illness based upon clinical impressions, history, vital signs, mental status, appearance of skin and mucous membranes, as well as the occurrence of other heat casualties.

It is imperative that the clinic secure an abundant supply of cool water; if potable water is limited, a secondary source of non-potable water should be considered for special purposes such as evaporative cooling. Fans and portable air conditioners may be sought from engineering units, and the dining hall should be approached regarding availability of ice, ice chests and cold storage. In arid settings, porous water bags will cool their contents to well below ambient temperature.

5.2 Air Transportable Hospital (ATH)

The ATH is deployable in increments of 14, 25, or 50 beds. Its mission includes holding patients for evacuation or return to duty within 2-7 days. Normal staffing can accommodate 12 major surgeries and a peak of 20 admissions per day. It includes two beds for resuscitative surgery and post operative stabilization. Outpatient services can provide definitive management for up to 50 patients/day. The ATH can relocate within 24 h, but it requires external support services. Each deployable increment of the ATH includes air conditioners, circulating fans and limited refrigeration capacity.

The first increment includes intravenous fluids (Ringers lactate, normal saline, and dextrose in water) totaling over 200 cases at 12 L/case; the second and third increments each include additional IV fluids. The ATH does not have freezer storage for ice and is limited on the amount of cold storage for oral fluids. The TA has recently been revised to may include high-reading rectal thermistorrs and supplies for preparing oral electrolyte solutions.

When heat casualties are anticipated, it may be advisable to augment the normal TA with intravenous fluids, rectal thermometers, urethral catheters, and pharmaceuticals for seizure control. The ATH Commander needs to determine the availability of support services to meet extraordinary needs for refrigeration, cold storage, oral electrolyte supplementation and patient holding.

6. PROTECTING PATIENTS AND STAFF

Medical personnel working in hot climates are themselves subject to heat stress and illness. Health maintenance is particularly important in this group because their duties involve a combination of physical effort, skill and judgment affecting the welfare of their patients. All personnel must be made aware that heat stress affects performance, and that critical tasks should be routinely double-checked. Minor complaints or signs of impaired performance call for immediate corrective action, since problems in one person often indicate impending trouble for others. Special attention must be given to new arrivals who may be very tired and have not yet adjusted to hot conditions, as they are especially susceptible to heat exhaustion.

Supervisors must enforce adequate work-rest schedules and sleep discipline and should also attend to their own sleep needs. Sleep deprivation reduces heat tolerance, and heat stress interferes with sleep. A sleep session should last 4-6 hours if possible, but naps are better than no sleep at all. Those who work at night require special consideration because they may have trouble obtaining adequate sleep during the day; every effort must be made to provide cool, quiet sleeping quarters for these people.

6.1 Water and Food

A special effort is required to provide fluids frequently to both patients and staff members, and they must be encouraged to replace fluid loss on an hourly basis. Drinks should be readily available, cool and palatable. Plain or flavored water is preferable to beverages which are carbonated, contain caffeine or are heavily sugared. Meals should be used to encourage complete rehydration by providing large cups or glasses and large containers of water and flavored drinks.

Both patients and staff should be encouraged to eat all scheduled rations in order to replenish calories used for work and salt lost in sweat. Depressed appetite and weight loss are common occurrences under hot conditions, and eating at least one hot, sit-down meal per day is the most effective single means of ensuring adequate food intake. Personnel must not skip meals by substituting candy bars, snack foods, sugary drinks or electrolyte beverages (sometimes called "sports drinks"), items which lack important nutritional components. Those responsible for planning meals should monitor dining areas and patient trays to see which foods go uneaten.

Field rations generally contain ample salt in the food itself, but diners should add salt to conventionally prepared meals. Neither salt supplements nor electrolyte drinks are necessary if personnel are eating normally. Salt pills are not a recommended form of supplementation, as excess salt intake is a real hazard, leading to increased water requirements, high urine output, nausea, and greater susceptibility to heat illness.

6.2 Pitfalls

Any lapse of discipline in control of food and water quality in a hot climate can have immediate, disastrous consequences. Precautions must be taken to prevent the zoonotic and human transmission of endemic diseases including bacterial, viral and parasitic types. Use of indigenous supplies for food and water and/or local personnel to handle them are potential sources of enteric infection.

Commercial flavorings neutralize water disinfectants. Flavoring should therefore be added just before use, and flavored water must be stored under refrigeration and handled in the same manner as foodstuffs. Because ice is a possible source of contamination, drinks should be cooled indirectly rather than putting ice in the beverage.

Ice is a common medium for the spread of gastroenteritis, a problem which seems to require rediscovery on every major military deployment. Ice is readily contaminated in manufacturing and handling and cannot be disinfected. Only ice from approved sources with tightly controlled sanitary storage and handling should be used in drinks. If there is

any doubt about its purity, the ice should be used for indirect cooling of the fluids to be consumed.

7. ASSESSMENT OF INCOMING PATIENTS

Heat stress and dehydration should be expected in all patients arriving directly from the field, transferred after stays at low-echelon treatment facilities or transported over long distances in uncooled vehicles. Rectal temperature must be determined at once and may require use of special high-reading thermometers; vigorous cooling should be instituted for values over 40 °C (104 °F). Unconscious or disoriented patients (whether they are sweating or not) should be treated as heat stroke cases until this can be ruled out. All arriving patients should be evaluated for electrolyte disturbances to the extent possible with available facilities.

Conscious patients suffering from fluid deficit should be rehydrated using oral mixtures, reserving parenteral solutions for patients who cannot drink or retain liquids. In an emergency, large volumes of intravenous fluid can be given in a short period as long as cardiovascular and renal function are intact; in doubtful cases, hydration should be evaluated using central venous pressure.

Patients who have been stabilized but must be held under hot conditions require high water intake to compensate for sweat production (Fig. 1). Patient hydration should be monitored by all means available at the facility, including physical examination, morning body weight, blood studies, urine flow rate and urine specific gravity or color. Urine dip sticks can be very helpful in this regard.

Heat stress and dehydration may alter the presentation of casualties; conversely, certain battlefield conditions may increase the risk of heat stroke. For instance:

- Rectal temperature rises by 0.3 to 0.5 °C for each 1% loss of body weight.
- Hyperthermia alters the relationship between heart rate and blood loss
- Dehydration lowers the threshold for hemorrhage-induced shock
- Hypovolemic vasoconstriction diminishes ability to dissipate heat
- Spinal injury impairs sweating capacity
- Sunburn inhibits sweating in affected areas
- Anticholinergic agents suppress sweating

8. HEAT ILLNESS MANAGEMENT

Fig. 2 depicts a diagnostic tree for the heat illnesses. Although several different heat illnesses were distinguished in the older literature, the progression from heat strain to heat exhaustion and heat stroke is now viewed as a continuum. Nonspecific heat strain and dehydration can produce a variety of symptoms related to the central nervous system, including diminished alertness, irritability, agitation or disorientation. The combination of heat stress and combat may produce a confusing neuropsychological picture which includes elements of Combat Stress Reaction. Physical signs of heat stress may include peripheral edema, muscle cramps, or syncope. Recovery can be expected with a few hours of rehydration and rest in cool conditions.

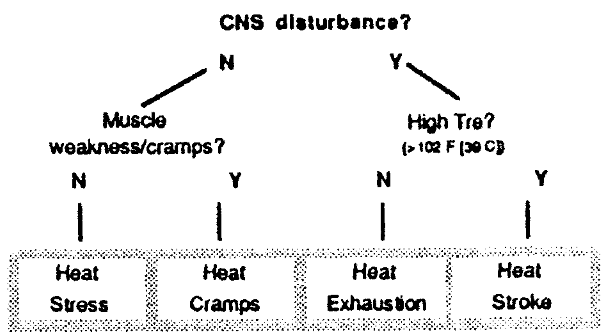

Fig. 2. Heat illness diagnostic tree.

Every effort should be made to obtain an accurate history with respect to conditions which may have precipitated heat illness and related problems:

- *Acute or chronic dehydration* due to inadequate fluid intake (shortage of potable water or conditions which inhibit drinking) or excessive fluid loss (vomiting, diarrhea, sweating or hemorrhage).
- *Electrolyte depletion* due to missed meals and/or plain water replacement for prolonged sweating.
- *Febrile illness* or recent immunization

- *Skin conditions* which interfere with sweating (heat rash, sunburn, chemical or thermal burns) or prevent evaporation (extensive dressings or other coverings)

- *Medications* affecting thermoregulation, for instance alcohol, amphetamines, anticholinergics,antidepressants, antihistamines, and phenothiazines, as well as exposure to toxins which cause tremors or muscle rigidity

- *Heat intolerance* as indicated by previous incidents of heat illness

8.1 Heat exhaustion

Signs and symptoms include various combinations of severe fatigue, irritability, headache, dizziness, nausea, vomiting, hyperventilation and syncope. Core temperature may be normal to moderately elevated. Due to its protean nature, heat exhaustion is generally a diagnosis of exclusion. Treatment consists of rest in a cool place (at least shade and good air movement) and vigorous oral rehydration. Intravenous fluids will be required if the patient cannot drink or retain oral fluids. Although full recovery may take 1-2 days, failure to respond promptly to treatment should raise the suspicion that the patient has suffered a mild heat stroke.

8.2 Heat stroke

This is a life-threatening condition characterized by elevated body temperature and mental confusion or loss of consciousness; the patient may or may not be sweating. Rectal temperature is usually in excess of 41 °C (106 °F) at the time of collapse, but may fall again before a reading can be obtained. Seizures are common. The differential diagnosis for heat stroke includes a variety of infectious diseases which cause fever and altered mental status, including encephalitis, meningitis, malaria, typhoid fever and typhus.

Rhabdomyolysis and renal failure are common in heat stroke incurred during physical exertion, and are associated with an elevated mortality rate; myoglobinuria may be detected as heme-positive urine dipsticks in the absence of red cells. Clotting disturbances are a late complication in severe cases. Patients with heat stroke suffer multisystem damage and retain increased vulnerability to heat stress for a period of months to years after their original injury, so that it is unwise to return them to duty under hot conditions (2).

The primary treatment for heat stroke is immediate reduction of internal temperature, as prognosis depends upon the amount and duration of hyperthermia. Various methods of rapid body cooling have been used over the years. Under field conditions the victim should be placed in the shade, stripped if possible, wetted down and fanned. At medical stations with refrigeration, the patient should be immersed in cool or chilled water to which ice is added when available. Ice packs or cold soaks may be substituted if immersion is not practical. Although some civilian clinicians advocate warm-water sprays with fanning as the optimal cooling technique, it does not provide the powerful cooling which is needed for exertional heat stroke (7). Intravenous solutions should be cooled before administration.

Because heat stroke patients need prolonged intensive care and supporting laboratory facilities, confirmed cases should be evacuated to major medical facilities as soon as they can be stabilized.

9. AIR EVACUATION

Heat stroke patients must be stabilized at rectal temperature < 38 °C and well hydrated with adequate urinary output. Seizures should be under control. Patients should have a functioning intravenous line and may require a urinary catheter, depending upon their level of consciousness. Complete medical records should accompany the patient, including a detailed account of fluid input and output and neurological findings. Conscious patients suffering from primary or secondary heat illness and dehydration should travel with prescribed quantities of oral rehydration mixtures or should have an open intravenous line for administration of fluid and electrolytes.

Aircraft parked in the sun are like ovens. Significant heat stress may occur among air crew members, maintenance personnel and passengers, especially in case of mechanical difficulties or cumulative delays. Heat casualties should not be loaded until just before takeoff unless cabin cooling systems are running on the ground. Night operations offer a cooler alternative for ground operations. Once airborne, the cabin environment is usually cool and sometimes cold.

9. SUMMARY

Recent US military operations in the Persian Gulf and in Somalia re-taught many of the lessons learned earlier concerning prevention and treatment of heat casualties. Furthermore, environmental heat stress is likely to assume growing importance in future military operations. Modern capacity for rapid airborne deployment makes it increasingly likely that troops trained in temperate climates or involved in winter maneuvers may suddenly find themselves working under hot desert or tropical conditions.

A flight surgeon who anticipates deployment to a hot climate or where NBC clothing may be required should review methods for preventing heat casualties and educate operational personnel in advance regarding appropriate precautions. New arrivals will be vulnerable to heat exhaustion and heat stroke due to the combined effects of sleep loss, circadian shift, dehydration, anxiety and unaccustomed physical exertion combined with environmental heat load.

11. ACKNOWLEDGEMENT

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